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U.S. NAVY FIRE RESEARCH BULLETIN
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The *U.S. Navy Fire Research Bulletin* is a quarterly periodical devoted to research and development efforts on a world-wide basis as they might affect the development and use of fire fighting equipment and techniques of the U.S. Navy.

Copies are available on request. Correspondence concerning the *Bulletin* and requests for copies should be addressed to the Editor.

The issuance of this periodical is approved in accordance with Department of the Navy publications and printing regulations.

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PREFACE TO FIRST ISSUE

The U.S. Navy today enjoys a position of unique technological leadership among the navies of the world for many reasons. Perhaps one of the lesser-known areas of advanced technical emphasis fostered by the Navy is its own in-house fire research program, dating back to small beginnings about 1934. In terms of the creating of a science from the art of fire fighting, the Navy's effort has been a fruitful expenditure of the nation's money. It has produced major advances in areas of research, technology, and operations that have previously had almost no national attention or support. Now the need for research in fire protection methods and materials is greater than it ever has been, but support of this difficult application of science is, unfortunately, not fully commensurate with the task.

Recognizing the importance of fire research to the Navy, the Director of Navy Laboratories, Dr. Joel S. Lawson, authorized initiation of this *Bulletin* on the general subject of fire research. As stated in his letter establishing the *Bulletin*, "the purpose of the publication will be to keep the Navy community informed of significant progress throughout the western world." Dr. John H. Huth, Director of Research and Development for the Naval Ship Systems Command, has given enthusiastic support to this enterprise and has helped formulate the contents.

From the vast literature that bears on fire protection, an attempt will be made to call attention to selected publications and articles dealing with basic research, fire technology, and fire suppression operations. This will be done by abstracts and editorial comments. It is clear that only a small portion of the field can be surveyed in any one issue, and the *Bulletin* will make no attempt to be encyclopedic. By this mixture and treatment of subject matter, it is hoped to increase the awareness of fire protection researchers to operating problems of the fleet and also to inform operating personnel of advances in technologies which might contribute to fire protection.

The editor invites comments from his readers in the interest of improving the usefulness of the *Bulletin*.

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RESEARCH RESULTS

1. R. Friedman, "A Survey of Knowledge about Idealized Fire Spread Over Surfaces," a review, Fire Research Abstracts and Reviews **10** (No. 1), 1 (1968)

This author examines a number of flame-spread test results on various materials by various experimenters under conditions of varying oxygen concentration, reduced pressure, sample orientation, wind speed, inert diluent gas, and direction of flame propagation. Theoretical considerations are discussed at length from many points of view, and the basic need for consideration of the chemistry of a combustible material is brought out. The author concludes that the intricate interplay of functions of the geometry of the sample, aerodynamic behavior of the flame gases, pressure dependency of the system, and energy transfer by conduction and radiation conspires against a universally applicable flame-spread theory.

Comment: Judging the rate of fire involvement of combustible materials, buildings, or equipment requires measurement and computation of a multiplicity of factors, including chemistry of composition, sometimes at instantaneous rates on the fire grounds—a feat not presently possible.

2. M. M. El-Wakil and M. I. Abdon, "The Self-Ignition of Fuel Drops in Heated Air Streams," Fuel **45** (3), 177-205 (1966); Fire Research Abstracts and Reviews **10** (No. 1), 16 (1968)

To extend previous investigations on fuel droplet combustion, where, in most cases, ignition was initiated by an auxiliary ignition source, the authors designed an apparatus in which an air stream could be sufficiently preheated to cause drops to *self-ignite*. The air, preheated in a ceramic heater, emerged through a nozzle giving flat velocity and temperature profiles in the experimental zone. The temperature history of the fuel drops was recorded by a high-speed potentiometer circuit, and high-speed cameras were used to determine flame histories within ±0.002 second. To eliminate problems of variability of physical characteristics of the fuel, pure straight-chain hydrocarbons were used as fuels.

This work shows that, in general, the physical and chemical ignition delays of fuels increase with the number of carbon atoms in the molecule and as fuel volatility decreases. The increase in droplet ignition delay is less marked at higher air temperatures.

Comment: This not-too-unexpected result serves as a reminder of boiler fuel light-off fires in naval ships. Since it is known that hot air ignites fuel sprays, personnel must exercise increased vigilance in the machinery space if higher volatility, lower-molecular-weight fuels are used in boilers.

3. R. N. Butlin and R. F. Simmons, "The Inhibition of Hydrogen-Air Flames by Hydrogen Halides," Combustion and Flame 12 (No. 5), 447 (1968)

The effects of hydrogen bromide, hydrogen iodide, and hydrogen chloride on the limits of flammability of hydrogen-air mixtures have been studied over a wide range of mixture composition and final flame temperature by varying the oxygen content of the air. The efficiency of these compounds in preventing flame propagation was found to decrease in the order HI, HBr, HCl, and it is shown that the iodide and bromide act as chemical inhibitors whereas the chloride acts predominantly as a thermal diluent. The primary inhibiting step in rich limit mixtures has been identified as the reaction of hydrogen atoms with the chemical inhibitor: $H + HX = H_2 + X$, which is in competition with the rate-controlling branching reaction: $H + O_2 = OH + O$. It is suggested that the relative efficiencies of the three halides reflect the reactivity with hydrogen of the halogen atom X formed in the above reaction.

Comment: Fire suppression chemists have always wondered—other things such as hygroscopicity and toxicity being equal—whether there would be an advantage in using potassium chloride or bromide in place of potassium bicarbonate as a fire-extinguishing agent. This paper begins to answer the question, at least concerning the chloride.

The subject requires further exploration in the development of dry chemical, free radical quenching agents.

4. J. R. Welker and C. M. Sliepcevich, "Burning Rates and Heat Transfer from Wind-Blown Flames," Fire Technology 2 (No. 3), 211 (1966)

Studies have been made of burning rates, flame lengths, wake temperatures, and flame radiation from wind-blown flames rising from liquid pool fires. Fuels examined were methanol, acetone, n-hexane, cyclohexane, and benzene.

Burning rates of fuel showed a decrease with increasing wind velocity, probably due to increasing flame tilt decreasing the rate of heat feedback to the pool of fuel. Flame radiation intensity increased slightly with increasing wind velocity, except for methanol flames, which showed a decrease. Radiant energy released from hydrocarbon fuel fires was measured as about five times that from acetone fueled pool fires.

Comment: These results are highly pertinent to a flight-deck fire on an aircraft carrier. Indications are that the fuel cannot be disposed of more rapidly by burning if the ship steams rapidly into the wind. A crosswind over the deck will increase radiation of heat during a fire. Carrier commands need standardized fire procedures.

5. A. Takata, "Mathematical Modeling of Fire Defenses," Final Technical Report, Project J6118 (Illinois Institute of Technology, Chicago), March 1969

A technique was developed to evaluate the effect of fire defenses on fires in buildings caused by a nuclear burst. These techniques were then incorporated in a fire-spread model. Three stages of fire involvement and severity (small, single-item fires; flashed-over room fires; and flashed-over fires burning longer than 5 minutes) were correlated with their management times by three classes of fire fighting teams (self-help teams, brigades, and fire department units). A fire-spread model was used. ("Development and Application of a Complete Fire-Spread Model: Volume I - Development Phase," A. N. Takata and F. Salzberg, Office of Civil Defense Contract N00228 67C1498, June 1968.) A computer procedure evaluated the effectiveness of the teams by a process of parameter-relationship computations based on statistics generated by experiments and accidental fire results. The computer results indicate that on the basis of a 10,000-building-tract model, one-fourth of the manpower available in that size tract can suppress all fires created by initial ignition of one-half or less of the buildings within a few hours. The self-help teams can be diverted to other activities after only minutes of initial effort.

Comment: The small fire-fighting tasks which ordinary citizens can accomplish at the immediate start of a wide-spread fire attack can be extremely effective, enabling professional personnel to concentrate on the most difficult aspects.

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TECHNOLOGY FINDINGS

1. D. H. Way and C. J. Hilardo, "Fire Tests on Thermal Insulation Systems for Pipes," Fire Technology **4** (No. 4), 271 (1968)

Thermal insulation systems used to conserve heat within high-temperature systems and to protect low-temperature systems from heat transfer were tested for their fire protection, degradation, and fire hazard characteristics under fire exposure followed by water spray and steam impingement. High-temperature insulation systems employing 1-inch-thick calcium silicate, magnesia, diatomaceous earth, asbestos fiber, and perlite composition were fire and water exposed, as were the following low-temperature insulation systems: cellular glass, cellular silica, vegetable cork, glass fiber, and cellular polystyrene and polyurethane. Various weather barrier outercoats using polyvinyl acetate or polyvinyl chloride mastic compositions were employed along with stainless steel forms of retainment (wires and thin sheets).

Each form of installation of these materials to the protected surface yielded its own characteristic results when exposed to fire and water impingement. Specific combinations and their fire characteristics are listed by the authors. In general, noncombustible thermal insulation presented no fire hazard. The tendency of cork to continue burning under a weather barrier and of cellular polystyrene to decompose into flammable gases and liquids presented hazards. Rigid cellular polyurethane presented no significant fire hazard because of its tendency to form char on fire-exposed surfaces. Cellular glass fragmented under the thermal shock presented. Fire damage and/or water damage was severe and would require partial or complete replacement of all insulation systems.

Comment: Apparently the use and design of thermal insulation systems with regard to their characteristics as fire hazards has been given little attention. Nothing seems to be fully satisfactory.

2. Caspar Reiter, "Chloride Damage from Fires Involving PVC Plastics," VFDB Zeitschrift Forshung und Technik in Brandschutz 17 (No. 1), 20 (Feb. 1968) (in German)

The increased use of plastics in so many construction and equipment applications often leads to serious after-fire damages. This investigation of hydrochioric acid and other chloride ion corrosion and damage resulting from fire decomposition of polystyrol, polyamide, and polyvinyl chloride plastics shows that corrosive gas and vapors diffuse to remote areas. Attack of metals is most often found.

Comment: We almost always neglect the design requirement for low toxicity and low corrosive vapor evolution under heat or fire attack on materials when we incorporate new equipment in naval installations. Closed atmospheres often increase the hazards resulting from fire damage.

3. K. Sumi and G. Williams-Leir, "Lethal Effects of Mattress Fires," Res. Paper 402, National Research Council, Canada, May 1969

A series of carefully modeled fires involving cotton mattresses ignited by smoldering cigarettes showed a flameless and glowless combustion which produced lethal amounts of carbon monoxide capable of killing a supine human in 70 to 80 minutes in a bedchamber 8 by 8 by 8 feet, even with a door ajar about two inches. Automatic water sprinkler heads above the bed area reached operating temperatures too late to save life in such fires. Treatment of an interlayer cotton twill pad between the sheet and the mattress with flameproofing launderable materials was effective in preventing ignition of the mattress by a carelessly dropped cigarette on the sheet of the bed.

Comment: Obviously, cotton mattresses are quite vulnerable to ignition and when smoldering are dangerous to sleeping persons. The newer foamed polymer mattresses have not been studied fully for fire characteristics. Such materials can melt and flow into the passage ways.

4. "Fluobrene," A Technical Note issued by Montecatini Edison, Milan, Italy, 1969, and presented at the May 1969 NFPA meeting.

"Fluobrene" is dibromotetrafluoroethane, a vaporizing liquid fire-extinguishing agent with high vapor density and low toxicity. Much important data have been compiled which show that this material is very promising and shows good fire-suppressing characteristics. Being used in the form of a vapor, it is applicable in cases where the dry chemical powders cannot be used because of their lack of gaseous properties.

Comment: This deserves further investigation because of the Navy's need for an extinguishing and inerting gas superior to carbon dioxide.

5. J. Nagy, A. R. Cooper, and E. J. Dorsett, Jr., "Explosibility of Miscellaneous Dusts," BuMines Report of Investigations 7208 (1968) From Research Report Digest No. 14 issued by the Federal Fire Council.

The explosion hazard of 319 different combustible dusts have been tested, and of these 181 were found to present a definite hazard. Minimum ignition temperatures, minimum explosion hazard, relative flammability, and other factors are given so that assessment of hazards is made easier for the qualified fire protection specialist.

Comment: This is good handbook data for those concerned with combustible dust mixtures. One should remember that many metals also burn.

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FIRE OPERATIONS INFORMATION

1. J. Milner, "Hong Kong's 'Lateral Technique' for Fighting Ship Fires," Fire International **2** (No. 24), 26 (Apr. 1969)

The fire protection facilities for Hong Kong harbor are quite different from those in other harbors of the world because of its large area (23 square miles), congestion of vessels within this deep anchorage, and lack of neighboring fire brigade assistance. A system of cargo-hold fire fighting has been worked out using carbon dioxide flooding and continual gas analysis.

An ocean-going fireboat is constantly available. This vessel carries 540 pounds of CO_2 with the normal large fire pumping capacities and foam-producing capabilities of such a tender. Upon discovery of a hold fire in an anchored vessel in the harbor, the holds are sealed and a CO_2 hose brought into the ship from the fire boat. Simultaneous with CO_2 flooding of the affected holds, gas analyzers are installed and pyrometers are employed to plot temperature trends in the fire area. Continued flame diminution by CO_2 in take (sometimes requiring 84 hours) will be indicated by a downward temperature plot. Then a team of fire fighters with hoselines and breathing equipment is sent into the hold through a jury-rigged air lock. This method has been successfully used even in typhoons.

Comment: This system is patterned after the successful Coast Guard tests of 1946 and published by them. Ship protection could well employ this in our congested harbor areas.

2. Dan Hooker, "Home Lightning Protection Reduces Fire Danger," Fire Journal **63** (No. 3), 20 (1969)

A new type of lightning arrester for dissipating high voltage surges from power-line lightning strikes has been labeled by Underwriters Laboratories Inc. According to the author of this article, the device senses the surge, opens the house electrical circuits, discharges the surge to ground, and then recloses for normal input, all in the time of microseconds.

Comment: This could prevent a large number of fires and damaged equipment due to sudden lightning-induced charges entering home circuits. The equipment differs from the old "gap" lightning arresters.

3. Walter R. Stone, "De-Icing Cable Not Listed for Roofs," Fire Journal **63** (No. 3), 36 (1969)

This article, a contribution by the editorial coordinator of the National Electrical Code, comes up with the startling fact that there is no electric heating cable that has been proven safe for melting snow and ice on roof edges. Evidently, enough troubles are being had with water pipe heating cables to make other installations very circumspect. Hot portions of cable occur where air exposure is allowed without metallic contact. Shorting out of cable sections occurs and grounding problems are prevalent. Wood shingle roofs, of course, are highly vulnerable.

Comment: Hazards may develop with the unsafe use of electric heating cables; perhaps they are being used by persons not aware of their true capabilities. Whereas UL listings on these devices may apply to certain specific applications, the devices are being used for applications for which they were never intended.

4. Gregory A. Harrison and David G. Lewoc, "Computer Fire and Resultant Circuit Card Fire Tests," Fire Journal **63** (No. 2), 5 (1969)

A fire was discovered in epoxy-based printed circuit cards in a computer. Later simulation tests showed that the fire originated in a capacitor which failed, then self-healed, but overheated to a temperature which ignited circuit cards normally considered to be noncombustible. The actual fire was detected by odor and had been extinguished by a portable CO_2 bottle before the smoke detector system went into action.

Comment: How many fire hazards are built into our expensive computer systems? Fire is more possible than we think, in almost every situation.

5. "Proceedings - Workshop on Mass Burns," published by National Academy of Sciences, Washington, D.C., 1969

This is a carefully edited volume of the papers presented at the Academy recently on the medical aspects of fire and flash burns. Under the sponsorship of the NAS-NRC Committee on Fire Research, it was supported by OCD, U.S. Forest Service, NSF, and NBS. The papers covered mass psychology, flash burns and scalds characteristics, complications and prevention of sepsis in burns, burn classification, and grafting procedures. Logistics, therapy, and other factors in high-yield-radiation burn conditions were also presented.

Comment: This is an admirable compilation of information on the subject. Medical terms are explained, and the present medical state of the art is well stated. Fire professionals would be interested in the attention devoted by medical people to this subject.

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NEWS NOTES

The new NFPA pamphlet "Fire Hazards in Oxygen-Enriched Atmospheres" has been published as NFPA No. 53M (80 pages, $3.00). It compiles the existing data and information about this problem and is noteworthy as our only single-volume collection of facts on these new hazards and their diminution.

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The July '69 issue of *National Safety News* is largely devoted to fire protection matters. Operating personnel might find useful information within its covers.

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Fire Officials are confronted with serious problems in training due to atomspheric pollution from preplanned fires used for instruction. The black smoke from hydrocarbon fuel fires is easily pinpointed. Efforts to circumvent this problem are costly but are going on. Simulation of fire by exposing personnel to infrared, by using white smoke fog (noncontaminating), by using lacrimators, by using predetermined casualty sequences and other devices are being tried as new forms of training. Gigantic afterburners to fully burn the black smoke from a training fire have been installed at the Navy Treasure Island Fire School.

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The CASS test and fire demonstration at China Lake is in its final planning stages. A small carrier flight deck is being erected there and efforts will be directed toward learning more about flight deck fires when operations begin at the site.

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Problems of lack of communications and insufficient standardization of course work at Navy damage-control schools were discussed at a recent meeting of school officials and BuPers leaders at Treasure Island in San Francisco. Unfortunately, the need for modernization of training methods was not brought up during the sessions.

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A new committee on Fire Research has been formed under the aegis of the Director of Navy Laboratories. This Committee, under the chairmanship of Dr. Homer Carhart of NRL, consisting of prominent scientists from Navy scientific groups, is studying the needs of the Navy in fire research.

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The Federal Fire Research and Safety Act has not been funded but the institution of regulations and tests for flammable fabric testing is proceeding well. A recent Washington, D.C. symposium on the subject of flammable fabrics revealed that the industry is "spending millions, collectively, on flammability R and D."

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Probably the most comprehensive special list of English language references to all the technical literature on fire is compiled and issued each year by the following activity:

Ministry of Technology and Fire Offices Committee
Joint Fire Research Organization
Fire Research Station
Boreham Wood, Herts, England

A recently received copy of "References on Fire"—Part XVIII, 1967—is one-half inch thick. It also covers nuclear safety subjects.

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Although there is much going on which could be included under the broad title of *Fire Research*, the support and continuation of applied studies in the prevention, control, and extinguishment of fires of all sorts is undergoing many difficult adjustments in the Navy as well as in industry. Budgets are at a new low for these efforts and personnel changes are many. The fire equipment industry has virtually ceased research efforts in the U.S. However, foreign interest seems to be picking up. The new dry chemical agent "Monnex" by Imperial Chemical Industries (England) is an encouraging note. This may prove to be twice as good an extinguishing agent as "Purple-K-Powder" (potassium bicarbonate).

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The changeover from English units of measurements to the recently adopted Système International refinement of the metric system is beginning to be felt in the fire services. Several articles on the SI system have appeared and they will be abstracted in future issues of the *Bulletin*.

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